Implementing NCEP Guidelines in a Web-based Disease-Management System

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DMS is a Web-based disease-management system, which facilitates easy access for users and close connection to hospital information systems, based on clinical practice guidelines. Currently we are prototyping DMS in the area of hyperlipidemia management. However our approach is general. For each office visit, DMS generates an encounter form with recommendations based on the National Cholesterol Education Program (NCEP) guidelines. In between visits, DMS provides email notifications to clinicians about delinquent laboratory studies and recommendations for patient management based on recently available information.

By reviewing previous efforts for implementing NCEP guidelines and some of the pitfalls that were encountered, we first constructed DMS for hyperlipidemia management. A detailed description of DMS is provided in this paper.

INTRODUCTION

This paper describes a disease-management system (DMS). Currently, we are prototyping DMS in the area of hyperlipidemia management. It provides easy access of web-based recommendations for the treatment of hyperlipidemia based on the National Cholesterol Education Program (NCEP) guidelines[1]. With the aid of the hospital information system MARS[2] at the University of Pittsburgh Medical Center (UPMC), DMS can automatically fetch patients' necessary laboratory works from MARS to fulfill the NCEP guidelines. Moreover, DMS not only communicates with MARS but also provides interactive data input from users via world-wide-web (WWW). The latter function is helpful in a small clinic without a central information system. In addition, a notification module in DMS, which provides e-mail notification, is designed to enhance the practical usage of the NCEP guidelines.

Many patients with hyperlipidemia ultimately develop coronary heart disease or generalized peripheral vascular disease, both of which are extremely important public health problems[3]. Recent large clinical trials have demonstrated that effective reduction of the low-density lipoprotein levels resulted in a significant reduction (30%) in morbidity and mortality in the study population[4]. However, this reduction in risk has not been generally achieved because of significant barriers to implementation of effective programs. In practice, fewer than 25% of patients with modifiable risk factors (smoking, hypertension and hypercholesterolemia) are being effectively treated. The discordance between accepted management standards and "usual practice" also exists in other common diseases such as hypertension and diabetes. Accordingly, there is a critical need to identify and to implement cost-effective web-based disease-management system in daily practice. DMS offers the potential to achieve this goal.

In this paper, we first review past experience in developing systems to implement guidelines and the problems that have been encountered in the process. Based on the lessons we learned, we present the desired disease-management system and DMS structure.

REVIEW OF NCEP GUIDELINES IMPLEMENTATION

The efforts of other investigators to implement the clinical guidelines were directed in three areas of research: a) representation of the guidelines in a computer format, b) incorporation of decision-support guidance into the clinical work flow, and c) improving compliance with the computer-generated advice.

Computer Representation of the Guidelines

One barrier to the implementation of practice guidelines is their complexity. This makes it difficult to represent the guidelines in a computer format. Schiffman et al[5] (1993) found that both decision tables augmented with probability and term subsumption considerably reduced the number of rules necessary to implement clinical practice guidelines.

Another barrier to computer implementation of clinical guidelines involved representation of the guidelines. Starren and Xie[6] (1994) compared three knowledge representation formalisms (CLASSIC, PROLOGUE, and CLIPS[7]) used to encode the NCEP guidelines. CLIPS was found to be the most useful way to conceptualize states and rules and to specify patient attributes. On the other hand, incomplete or

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ambiguous portions of the guidelines make computer implementation difficult[8,9].

Incorporation of Decision Support Guidance into the Clinical Work Flow

The Hyperlipid Advisory System[10] (HAS) employed at Stanford University used a commercial expert system, *Nexpert Object,* and a flat-text database format supported by *Nexpert* to implement NCEP guidelines. The major contribution of HAS to the implementation of NCEP guidelines was the incorporation of a temporal interface and the addition of time-stamped events as operational features of the program. HAS had the drawback, however, of being available only on individual personal computers. It is also necessary to enter individual patient data manually into the computer before a computer-generated patient management recommendation can be obtained. Similarly, the work of Starren and Xie[6] requires query of the expert system at the time of patient visit. The need to interact with the computer at the time of each individual patient visit imposes significant constraints on time efficient management of patients.

Increasing Compliance with Computer-Generated Advice

Another barrier to implementation of practice guidelines is a lack of physician compliance. Lobach[11] (1996) conjectured that the best way to enhance clinician compliance with clinical practice guidelines was to have computer-generated, individualized feedback reminder communication via e-mail biweekly. The Computer-Assisted Management Protocol[12] (CAMP) developed at Duke University applied this technique for management of patients with diabetes mellitus. That resulted in a 35% physician compliance rate in the intervention group compared to 6.1% compliance in the control group.

Based on the barriers identified in the information systems reviewed, we list basic design principles that should be incorporated into future DMS designs: (1) time-stamp usage on patient data and relational database employment, (2) rule-set reduction, (3) CLIPS language for coding guidelines, and (4) e-mail notification of physicians.

Finally, the importance of strategic organization of preventive care services deserves emphasis. In this regard, DMS is designed to coordinate the efforts of all personnel involved in the management of the hyperlipidemic patients. The system design also incorporates concurrent communication and feedback to the physician and, in turn, to the patient so that there is a continued emphasis on compliance with the guidelines. These broad-based features have all been shown to enhance the effectiveness of a disease-management system.

DESIRED DISEASE-MANAGEMENT SYSTEM

A well-designed disease-management system not only includes the basic design principles listed above but also has the capabilities described below.

Easy accessibility of the information system is an important factor. Due to its widespread availability, ease of use, low cost, and multimedia support, the World Wide Web has become the most popular tool used by an overwhelming majority of individuals to access information on the internet and intranet. In addition, it is platform-independent and provides an essential medium for the global dissemination of biomedical information through client-server techniques[13]. Thus, DMS with Web interface offers an ideal configuration, which enhances accessibility and thus applicability of the program over a wide network. Communication with physicians via patient encounter forms structures the physician's activities and allows easy incorporation of computer-generated recommendations into the clinical work flow at the time the patient is being seen. Data-entry personnel improve the efficiency of the information exchange so that very little of the physician's time is required. Moreover, patient encounter forms provide the most recent laboratory data on the patient as well as information on the patient's previous medication. These features encourage uniform patient care and compliance with computer-generated recommendations.

The very important task of ensuring routine patient follow-up is an integral part of DMS[14]. Routine surveillance of a patient's database automates requests for additional patient laboratory studies and follow-up visits in a timely fashion. This is an essential feature for assuring patient compliance by providing positive feedback to both patients and physicians. The design features in DMS include: 1) the use of the CLIPS language, 2) patient encounter forms to communicate recommendations, 3) a widely accessible Web-based interface, and 4) periodic e-mail communication with physicians to alert them of updated laboratory information and management recommendations.

ARCHITECTURE AND METHODS

Architecture of Web-based DMS

We developed DMS on a UNIX Sun-Sparc workstation. DMS has three major functions: (1) form generation, (2) data capture, and (3) inter-visit

event processing. Patient encounter forms are generated by Web Intelligent Notes (WIN), a DMS module as shown in Figure 1, prior to the patients' visits. The event processing module sends e-mail alerts to clinicians about events that occur (or fail to occur) between visits. The Data-Fetch module retrieves patients' laboratory information from a central laboratory database (MARS[2]) at the University of Pittsburgh Medical Center. This feature provides an alternative way for accessing patient data instead of entering data manually. Figure 1 shows the Web-based DMS architecture. The following section is an explanation of the workflow supported by the system depicted in Figure 1.

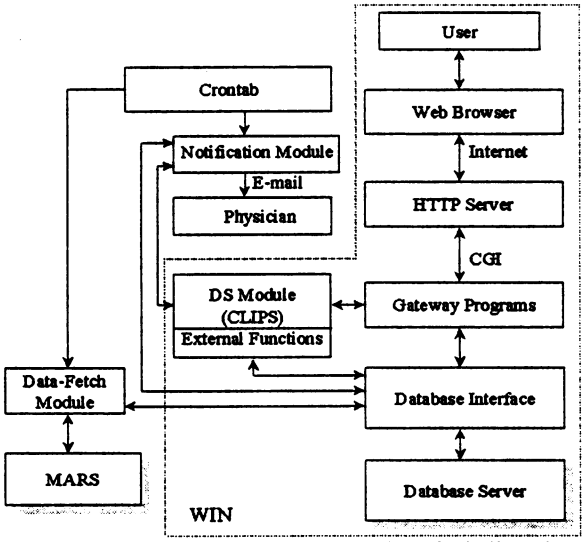

Figure 1: DMS architecture. The dash-line box represents the module, Web Intelligent Notes (WIN).

Methods

To access WIN, a user (most likely a data-entry person in a practice) enters WIN's uniform resource locator (URL). The hypertext transfer protocol (HTTP) server then transfers an HTML form which requests login information (user name and password).

A gateway program through the common gateway interface (CGI) manages the login procedure. The gateway programs, mainly written in Perl, control various functions of the WIN, *e.g.*, user checking, patient registration, patient data entry. Perl is a freely distributed language and is a powerful tool for pattern matching and report generating. If the user name and password are valid, the gateway program shows function buttons listed in the left column of the Web page, as shown in Figure 2.

At this point, the user may create or update a patient record by clicking "Patient Regist." button, as shown in Figure 2. The registration data is passed into a gateway program. Within the gateway program, the data is delivered to a database server through the database interface. The database interface, written in C and Perl, can accept a Structured Query Language (SQL) command and pass it into a database server. We use MiniSQL[15], a relational database management system (RDBMS). This RDBMS is supported on a variety of platforms and operating systems. We use a Perl API MsqlPerl[16] as an interface to MiniSQL.

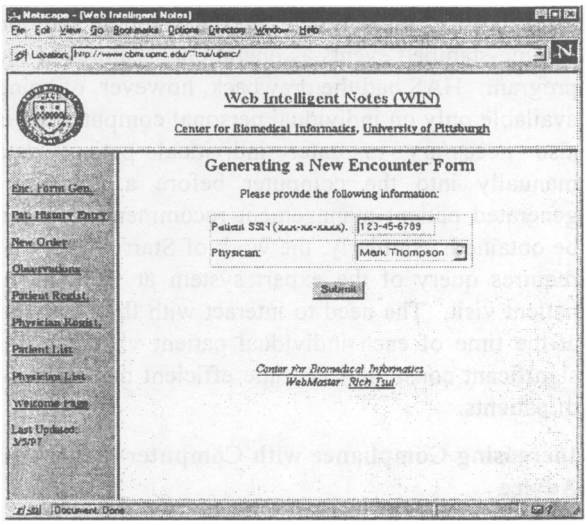

Figure 2: Screen to generate an encounter form via WIN.

The user may also generate an encounter form for an upcoming patient visit by clicking the "Enc. Form Gen." button, then entering the social security number (SSN) and selecting a physician's name, as shown in Figure 2. An encounter form generated by WIN contains disease-specific management advise communicated as requests for observations and then suggested orders. WIN does this by running the decision support (DS) module which contains an encoding of NCEP guidelines, modified from Starren and Xie's CLIPS codes. The DS module uses C functions to access patient data from the database server.

During the visit, the clinician uses the encounter form to document the visit. Specifically, the clinician records the requested observations on the form and circles those orders that he endorses.

After the visit, the data on the encounter form is transcribed by office personnel into the database using WIN. The clerical staff log in to WIN and bring up a data entry form for that visit.

In between visits, the inter-visit event processing module is activated automatically at midnight (by a crontab in UNIX). For each patient registered in the

patient table, this process searches the database for events of interest. Events of interest include (1) new laboratory results, (2) delinquent laboratory studies, (3) missed appointments, and (4) medication changes. It then loads the events into CLIPS, loads other data about the patient into CLIPS, and then runs CLIPS to identify any delinquencies or changes in disease management dictated by the recent data events. If CLIPS suggests recommendations, the DMS communicates them to the responsible clinician via e-mail.

RESULTS

We have modified the CLIPS code for NCEP guidelines contributed by Starren and Xie[6] and have added drug treatment in the CLIPS code. Thus, the CLIPS engine looks into a database first for information. If the required datum is not available, the CLIPS engine will inform DMS to ask for necessary observations on an encounter form. Our approach is to cluster requests instead of using the interactive-session mode that was employed by Starren and Xie. Currently ninety-four CLIPS rules have been developed for hyperlipidemia management. So far, we have run DMS on nine test cases and have demonstrated that DMS can generate recommendations for data collection and management in accordance with NCEP guidelines through a sequence of visits up to the point of requiring pharmacological intervention.

Figure 3 is an example of an encounter form for a new patient. It illustrates the DMS guideline-driven gathering of information. Note that if the requested risk factor information is not provided on this encounter form and it is not captured by some other mechanisms prior to the next visit, the DMS will request it again on the encounter form for the second visit.

DISCUSSION AND FUTURE WORKS

At the start of this project, the state-of-the-art in NCEP guideline implementation was represented by the HAS at the Stanford University, which demonstrated that this set of guidelines (not including drug therapy) could be represented in a rule-based expert system with time information of events and a relational database. This level of implementation has not proven sufficient, however, to improve adherence to the NCEP guidelines. In this project, we employ techniques that previously had been shown to favorably influence clinician and patient behavior. We use computer-generated encounter forms that request observations and provide suggestions for orders. This type of form has been in use at the Regenstrief Institute in Indianapolis in the outpatient setting for nearly three decades and fits well into the outpatient workflow, and, more importantly, is known to be effective in increasing compliance with simple guidelines (e.g., check potassium in patients on diuretics). We are also drawing upon techniques used in clinical event monitoring[17], such as the use of expert systems to monitor asynchronous data events and to bring anomalies and potential deficiencies of care to the attention of clinicians. Here, the question of whether such techniques will be effective in outpatient disease management has not yet been answered. Lobach's success in improving physician compliance using an educational effort based on e-mail communication is cause for optimism.

We plan to add error checking and data computing by using the Java[18] programming language for client-server functions. Our future plans also include the investigation of DMS performance in a real clinical setting.

We also believe that another component a disease-management system must have is the capability to interact with the patient in order to promote behavioral modification in the areas of diet, exercise, and drug therapy. We are just beginning to work on the problem of how such components overlap with our current approach to knowledge base and software development. Our long-term goal is to coordinate a palette of disease-management tools.

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John Doe DOB: 1/1/50 SSN: 123-45-6789 Appointment Time: 3/13/97 11:00 1234 Forbes Ave. Pittsburgh, PA 15213	Mark Thompson Phone: 647-7812 Email: thomps@card2.cath.upmc.edu S557 Scaife Hall Pittsburgh, PA 15213

1 CLINIC VISIT, 2 CLINIC CONSULT, 3 CONSULTATION, 4 RX REFILL, 5 NO CHARGE

Risk Factors

1. Family history of premature atherosclerotic disease,
   Father/mother or 1st degree relatives < 55/65, Myocardial infraction or sudden death: yes____ no____
2. Coronary heart disease: yes____ no____
3. Smoking: yes____ no____
4. Hypertension if SysBP 140 and DiaBP 90: yes____ no____
5. Diabetes mellitus: yes____ no____
6. Woman Only
   Estrogen-replacement therapy yes____ no____
   Premature menopause yes____ no____

Diagnoses

1. Obesity: yes____ no____
2. Peripheral vascular disease: yes____ no____
3. Cerebral dascular disease: yes____ no____
4. Renal disease: yes____ no____
5. Thyroid disease: yes_____ no____
6. Proteinuria: yes____ no____
7. Angina: yes____ no____
8. Atherosclerosis: yes____ no____

Observations List	Orders
1. Right arm BP:(Sys.) _____ mmHg (Dia.)____ mmhg 2. Left arm BP: (Sys.) _____ mmHg (Dia.)____ mmHg 3. Height _____cm 4. Weight _____kg	• Total cholesterol • HDL cholesterol

Staff: _____ Signature: _____

3/12/97 Encounter Date	Provider ID	Return	Return Provider	/ / Next Appt Date	Medicine Service Area

Visit times : 1

Encounter Form No.: 9

Figure 3: An Encounter Form for an Initial Encounter